12

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

AD A027567

HYDROMECHANICAL PERFORMANCE EVALUATION OF A SUBMARINE TOWED COMMUNICATIONS BUOY MODEL

by

Bruce Webster

and

John F. Campbell

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

SHIP PERFORMANCE DEPARTMENT
DEPARTMENTAL REPORT

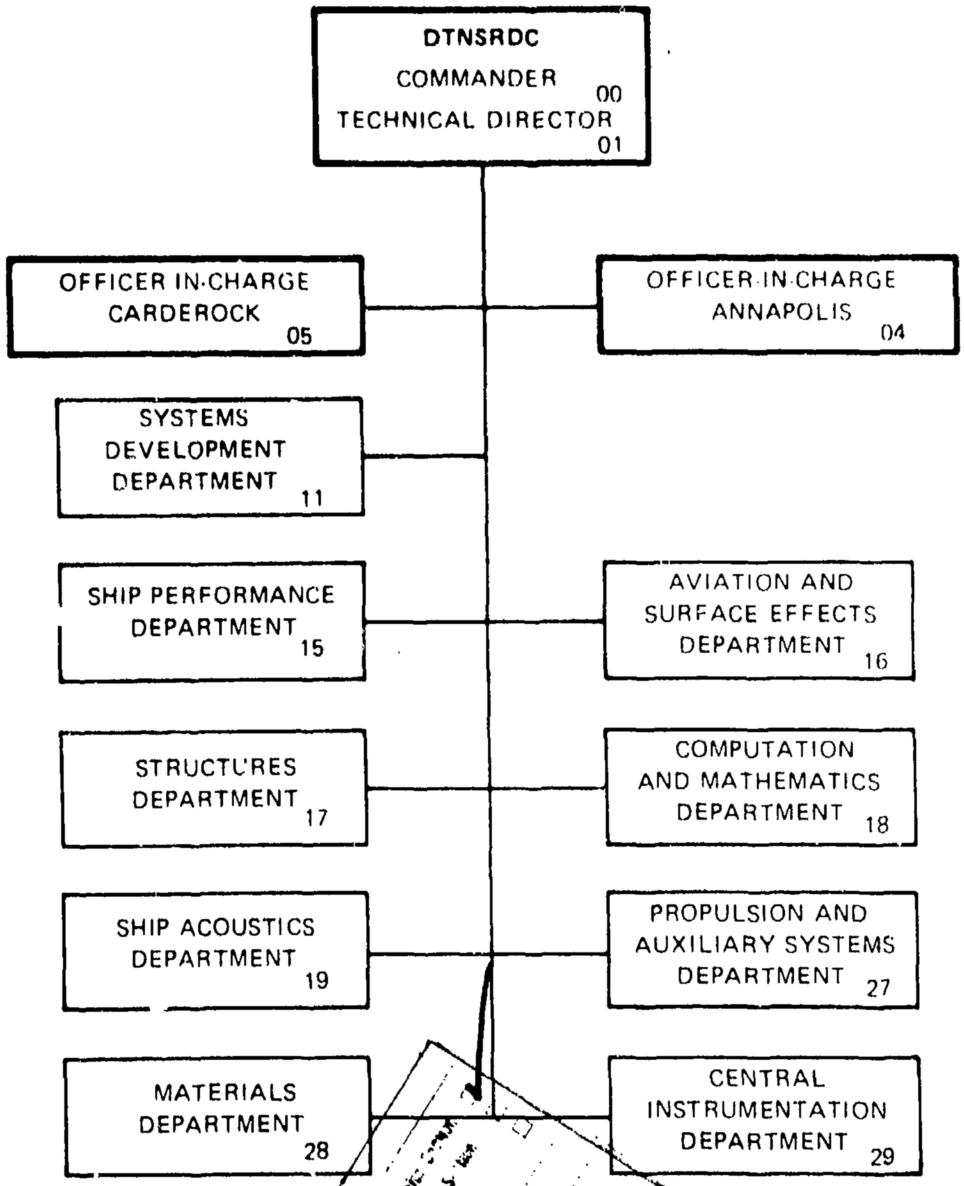
APRIL 1976

REPORT NO. SPD-661-01

Report No. SPD-661-01

"Experimental Hydromechanical Performance Evaluation of a Submarine Towed Communications Buoy Model",
by Bruce Webster and John F. Campbell (April 1976)

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

14 SPD-661-01

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

6 Experimental Hydromechanical Performance Evaluation of a Submarine Towed Communications Buoy Model.

5. TYPE OF REPORT & PERIOD COVERED

9 Departmental rept.

6. PERFORMING ORG. REPORT NUMBER

SPD 661-01

7. AUTHOR(s)

10 ~uce Webster [redacted] John F. Campbell

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

David W. Taylor Naval Ship Research and Development Center
Bethesda, Maryland 20084

12 32p.

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

18 Task Area XF 2122[redacted]
Work Unit 1-1548-214

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Electronic Systems Command
Information System Division
Washington, D.C. 20362

17 XF21-222-702, SF14-222-006

12. REPORT DATE

11 Apr[redacted]76

SF14-222

13. NUMBER OF PAGES

27

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release - Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Towed Buoys
Submarine Communications
Hydromechanics
Buoy Stability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The towing performance and stability of a buoy model having a NACA 4424 profile shape were experimentally investigated to explore the feasibility of developing a buoy to operate from submarines at higher speeds and deeper depths than were previously obtainable. Buoy parameters of tension, cable angle, pitch, roll and depth were measured for several towpoint locations, static depths, antenna conditions and stabilizer angles. Results indicate that a buoy with a NACA 4424 shape will perform satisfactorily at speeds up to 25 knots.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

389 694 mt

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ADMINISTRATIVE INFORMATION

The research and development program described in this report was funded by the Naval Sea Systems Command under Program Elements 2720N, Task Area SF14.222.006, Task Order 15350, Naval Ship Research and Development Center Work Unit 1-1548-204.

INTRODUCTION

The Naval Sea Systems Command (NAVSEA) requested the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) to explore the feasibility of developing a wingless, lifting buoy to act as a near surface platform for communications antenna(s) for deeply-submerged, high-speed submarines. Existing towed communications systems do not meet the high-speed performance requirements established in SOR 32-03. To develop a significant improvement of system performance, efforts must be focused on: (1) improved buoy hydromechanic performance and structural integrity for buoy operation at high speeds near the surface; and (2) improved hydromechanical and structural towline performance.

The Center, at the direction of NAVSEA, conducted theoretical and experimental hydromechanic performance evaluations of buoys based on two candidate profile shapes. The candidate shapes were: (1) NACA 4424, and (2) a high-lift shape developed by the McDonnell-Douglas Corporation. Results of these evaluations[1] indicate that the NACA 4424 shape buoy

[1] Campbell, J.F., "Comparison of Hydrodynamic Performance of Two Candidate Shapes for use as Submarine Towed Communications Buoys," NSRDC SPD Report 562-01 (May 1974).

has the more favorable performance characteristics by providing higher lift-to-drag ratios, lower towline tensions, and greater pitch stability at small angles of attack. The NACA 4424 shape buoy was selected for further investigation. A model of this buoy was constructed for the purpose of examining its hydromechanic characteristics with a modeled AN/BSQ-5 Submarine Communications Buoy System whip antenna, an antenna winch, and a servo-controlled horizontal stabilizer.

This report documents the work performed in evaluating, at speeds up to 25 knots, a fiberglass buoy model having a basic NACA 4424 profile shape. Descriptions of the model, measurement system, control mechanisms, and experimental procedures are given. Experimental data are presented graphically for towline tension, towline angle at the buoy, buoy pitch angle, and total lift-to-drag ratio as functions of speed. A buoy configuration is recommended to provide desired operational performance, and those areas requiring further investigation are identified.

MODEL DESCRIPTION

Three configurations as shown in Figure 1 were examined during the investigation: without the whip antenna and with the antenna in the extended and retracted positions. The physical characteristics of the model are listed in Table 1. The model consists of a 3/16-inch (4.76-millimeter) thick fiberglass shell having a basic NACA 4424 profile

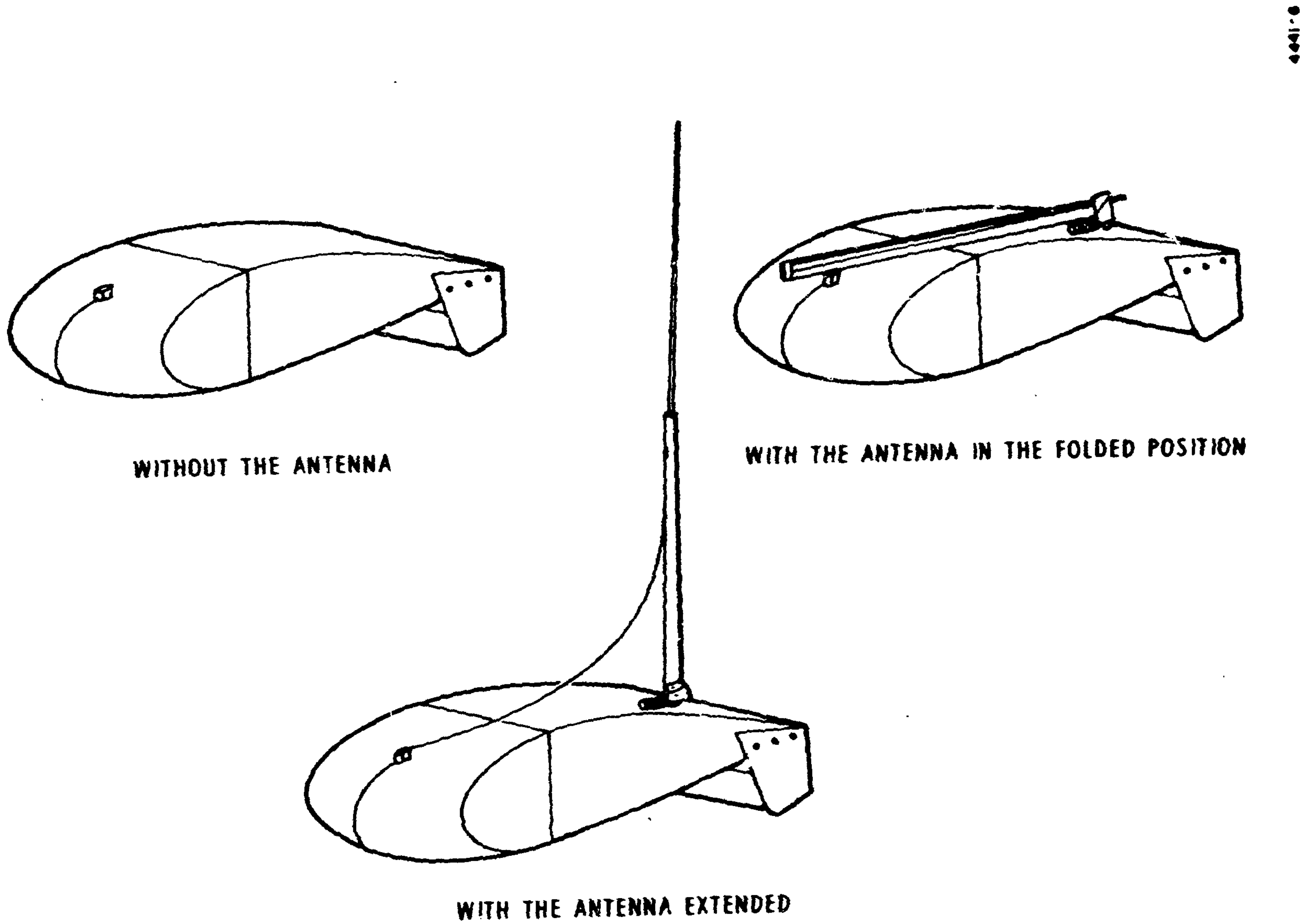


Figure 1 - Buoy Antenna Arrangements

TABLE 1 - PHYSICAL CHARACTERISTICS OF THE NACA 4424 MODEL

Buoy Shell		
Chord, feet	3.0	(0.914m)
Span, feet	1.17	(0.357m)
Height, feet	0.72	(0.219m)
Nominal Wall Thickness, inches	0.188	(4.775 mm)
Aspect Ratio	0.39	
Volume Displacement, cubic feet	1.55	($0.144m^2$)
Net Buoyancy Without Antenna, pounds	38.5	(171.3N)
Net Buoyancy With Antenna, pounds	35.6	(158.4N)
Tail Assembly		
Vertical Fins (2)		
NACA Section-Shape	0012	
Root Chord, inches	7.0	(17.78 cm)
Tip Chord, inches	5.0	(12.70 cm)
Span, inches	6.0	(15.24 cm)
Area, square inches	36.0	(232.3 cm^2)
Aspect Ratio	1.0	
Taper Ratio	0.72	
Sweep Angle of 1/4-chord, degrees	14.0	
Horizontal Fin		
NACA Section-Shape	0012	
Chord, inches	5.65	(14.35 cm)
Span, inches	13.0	(33.02 cm)
Area, square inches	73.5	(474.2 cm^2)
Aspect Ratio	4.35	
Taper Ratio	1.0	
Sweep Angle, degrees	0	

section shape, a fiberglass tail assembly, and internally housed measurement and control systems. The fiberglass shell is parted transversely at a point 33 percent of the chord length from the leading edge to allow access to the internal components. In planform, the leading edge of the shell is contoured elliptically to fair tangent to the parallel sides at approximately 20 percent of the chord length. The tail assembly is attached externally at the stern of the shell and consists of one horizontal and two vertical fiberglass stabilizers. The physical characteristics of the tail assembly also are identified in Table 1. The horizontal fin has an adjustable incidence angle setting of ± 16 degrees relative to the bottom of the vertical fin. The sign conventions and reference planes for the horizontal stabilizer angle, the buoy pitch angle, and the towline angle at the buoy are defined in Figure 2. A towpoint bracket containing towpoints at 37 and 40 percent of the chord length from the leading edge is located internally on the longitudinal centerline of the shell. The other internal components include an electronic measurement system and electromechanical control units which are described in the following paragraph. The remaining internal volume is filled with styrofoam having a density of 4 pounds per cubic foot (64.1 kilograms per cubic meter).

DATA ACQUISITION AND CONTROL SYSTEMS

A schematic of the data acquisition and control systems is shown in Figure 3. The data acquisition system consists of transducers measuring towline tension, towline angle at the buoy, buoy pitch and roll

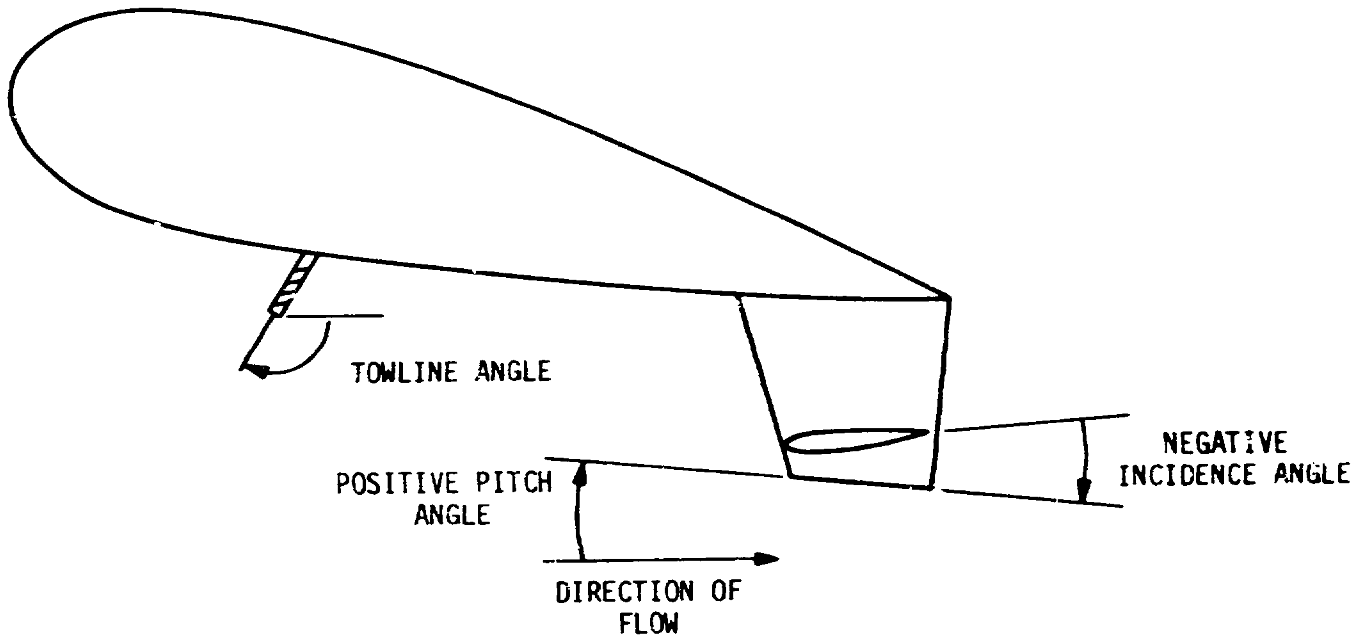


Figure 2 - Buoy Reference Planes and Sign Conventions

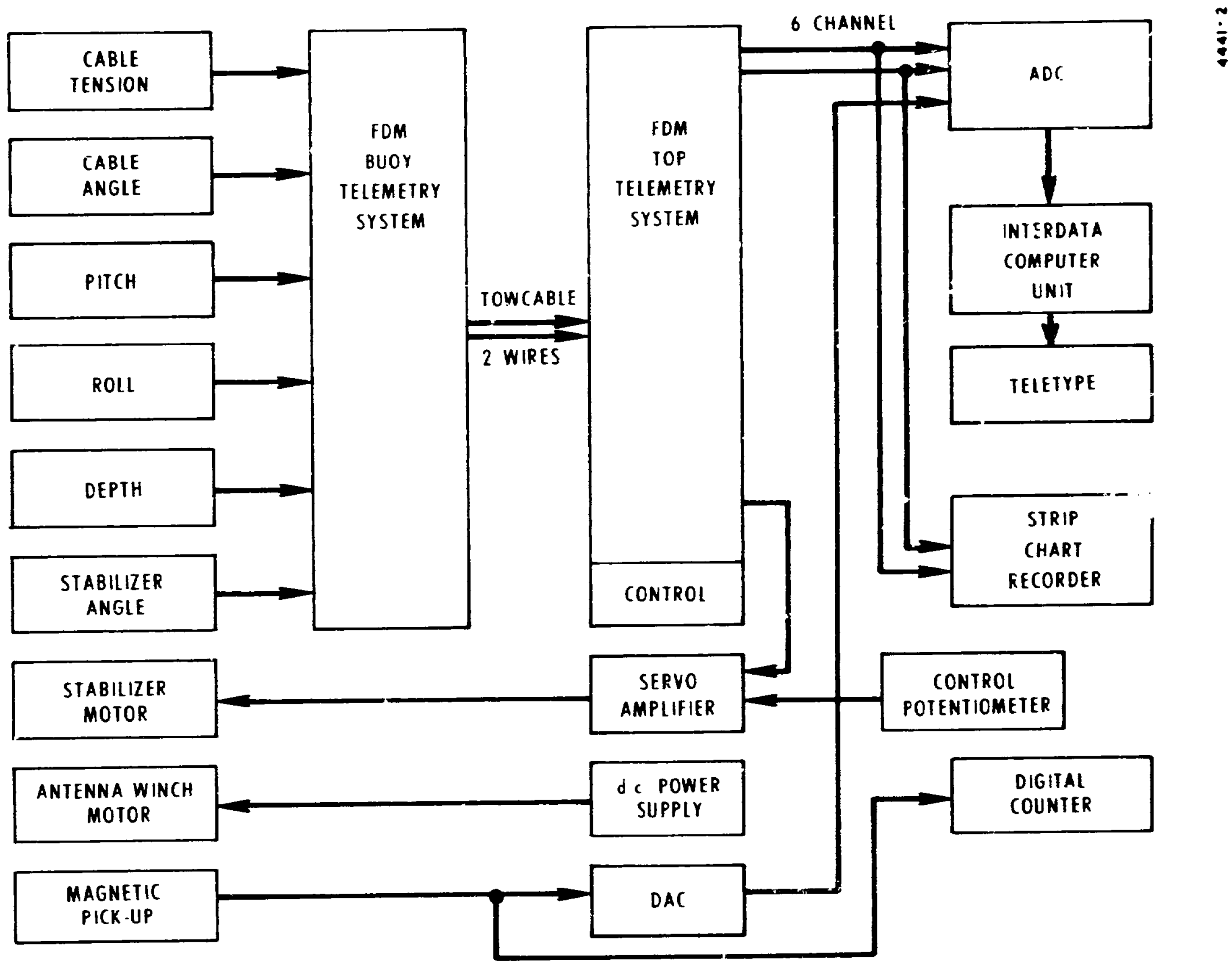


Figure 3 - Schematic of Data Acquisition and Control System

angles, buoy depth, and horizontal stabilizer incidence angle. The type, range, and accuracy of these transducers are identified in Table 2. Measurements from the transducers were transmitted to a frequency-division-multiplexing (FDM) unit contained in the buoy, which modulated and transmitted the signals through two electrical conductors in the towline. The signal voltages were demodulated and recorded on a strip chart recorder on the carriage. Simultaneously, the demodulated signals were fed to an analog-to-digital converter and the digitized signals were used as inputs to an Interdata Model 70 computer system to obtain 5-second averaged values of the measured data.

TABLE 2 - MEASUREMENT DATA ACQUISITIONS SYSTEM TRANSDUCER CHARACTERISTICS

Measurement	Transducer Type	Range	Accuracy
Tension	Strain-Gage Shear Pin	1500 pounds (6672.3N)	±7.5 pounds (±33.36N)
Cable Angle	Pendulous Potentiometer	±20 degrees	±0.2 degrees
Pitch Angle	Pendulous Potentiometer	±15 degrees	±0.15 degrees
Roll Angle	Pendulous Potentiometer	±15 degrees	±0.15 degrees
Depth	Potentiometer	35 feet (10.67m)	±0.35 feet (±0.107m)
Stabilizer Angle	Potentiometer	±20 degrees	±0.20 degrees

Antenna extension and retraction is controlled by the operation of a small winch/motor unit located in the forward section of the buoy Reeling a wire rope onto the winch folds the articulated antenna mast forward Reversing the winch allows the spring mechanism in the antenna base to extend the antenna. The antenna in three sequential positions is shown in Figure 4.

A servo-controlled motor drives a worm/worm gear assembly to adjust the angle of the horizontal stabilizer. Rotation of the worm gear is transferred to the horizontal stabilizer by two interconnected, [illegible]ting linkage arms extending through an enclosed slot in one of the vertical fins. The planform arrangement of the data acquisition and control systems in the buoy shell is shown in Figure 5.

EXPERIMENTAL PROCEDURE

The hydromechanic performance of the buoy model at the near-surface and submerged deeply was experimentally evaluated in the high-speed towing basin For the near-surface the model was towed from a twin vertical strut assembly using a ribbon-faired, 0.347-inch (8.81 mm) diameter double-armored towline which was passed through a faired tube up to the carriage, as illustrated in Figure 6. This arrangement provided for maintaining a relatively constant near-surface buoy depth.

To evaluate the buoy at a deep depth, the model was towed inverted using the arrangement shown in Figure 7. With this arrangement, the model was ballasted to a weight in water equivalent to its initial net buoyancy It then was trimmed with an equivalent static pitch angle.

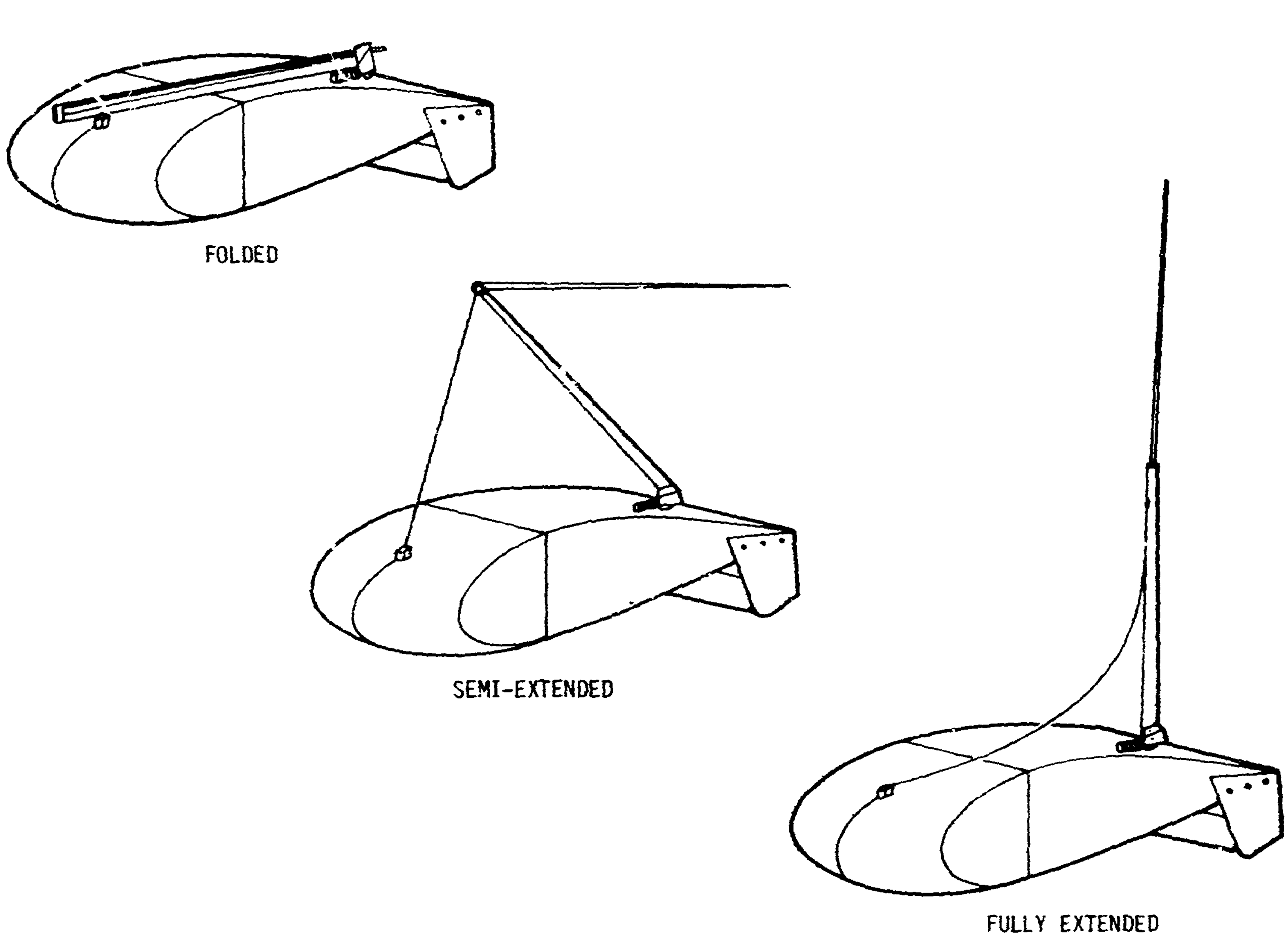


Figure 4 - Antenna Extension Sequence

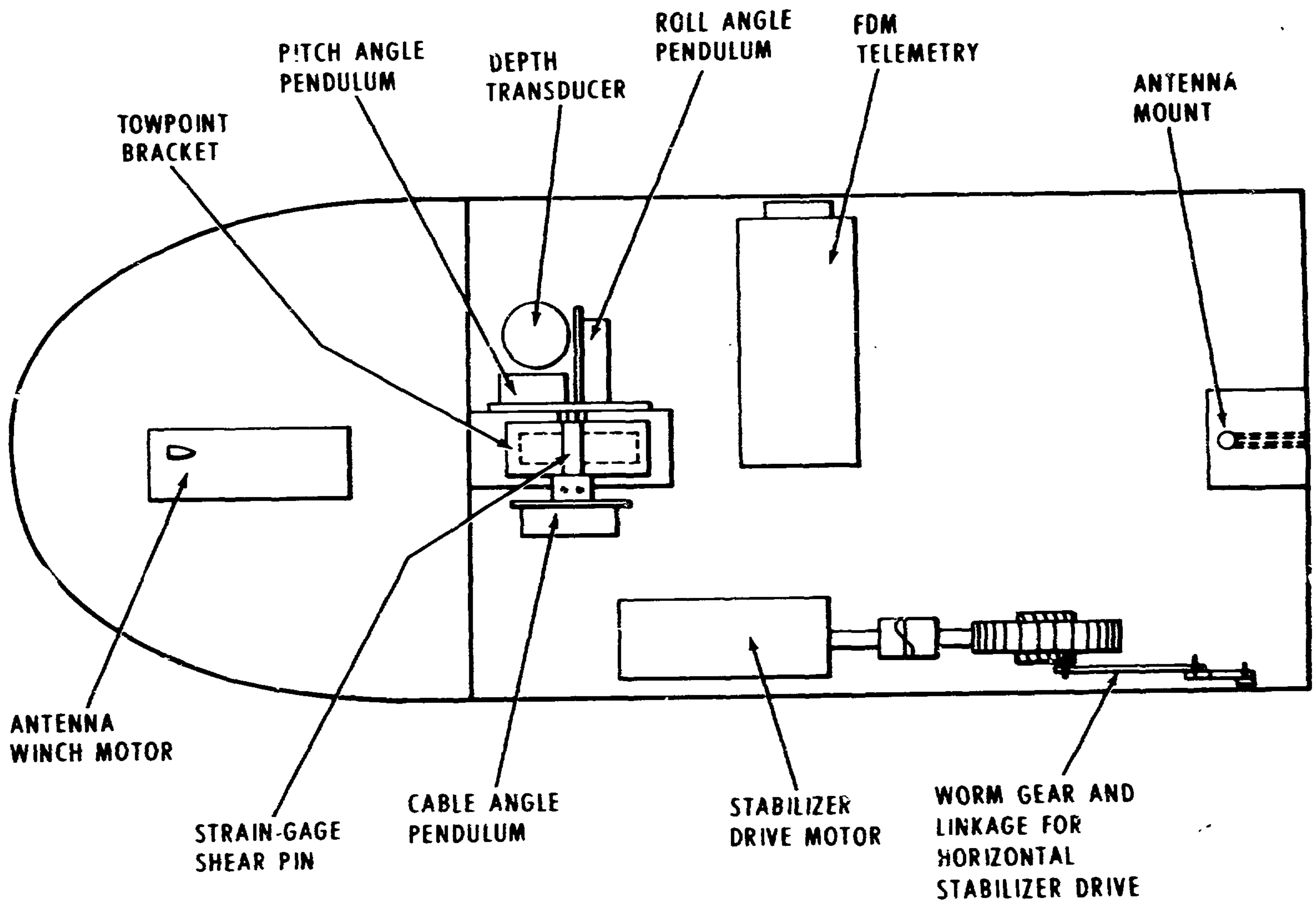


Figure 5 - Internal Planform Arrangement of Data Acquisition and Control System

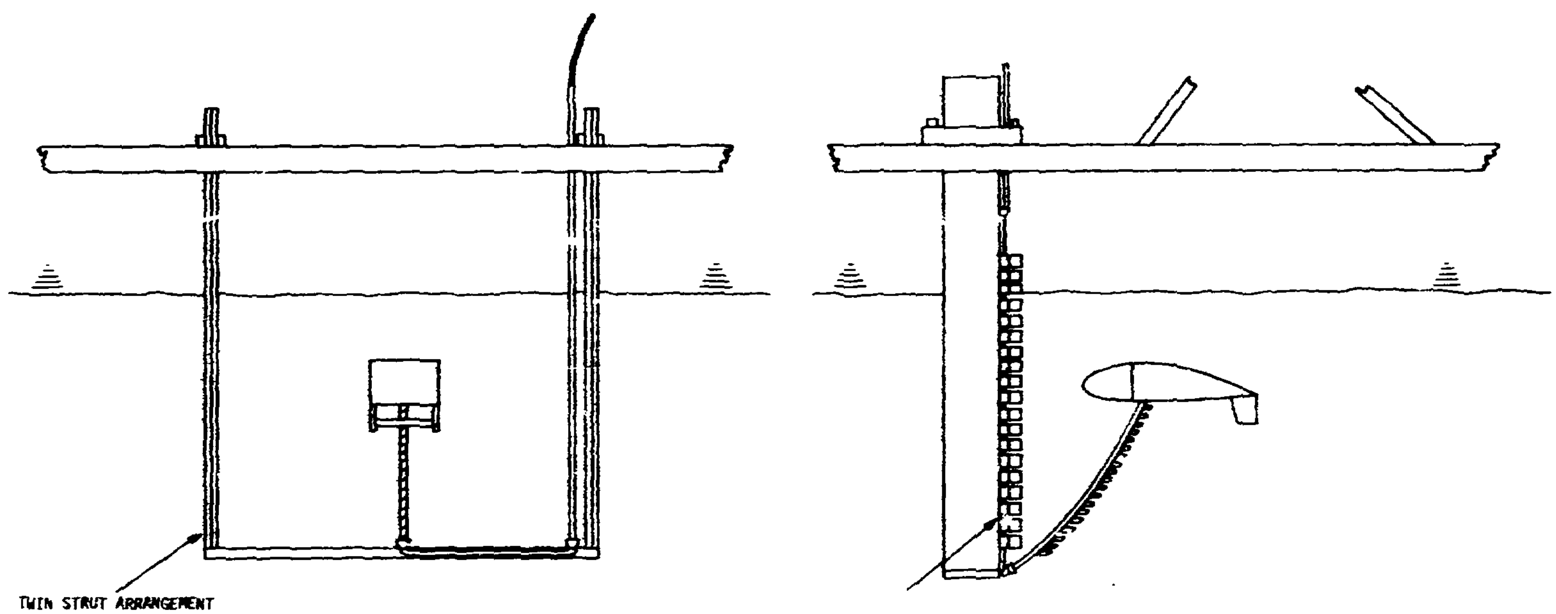


Figure 6 - General Towing Arrangement for the Near-Surface Condition

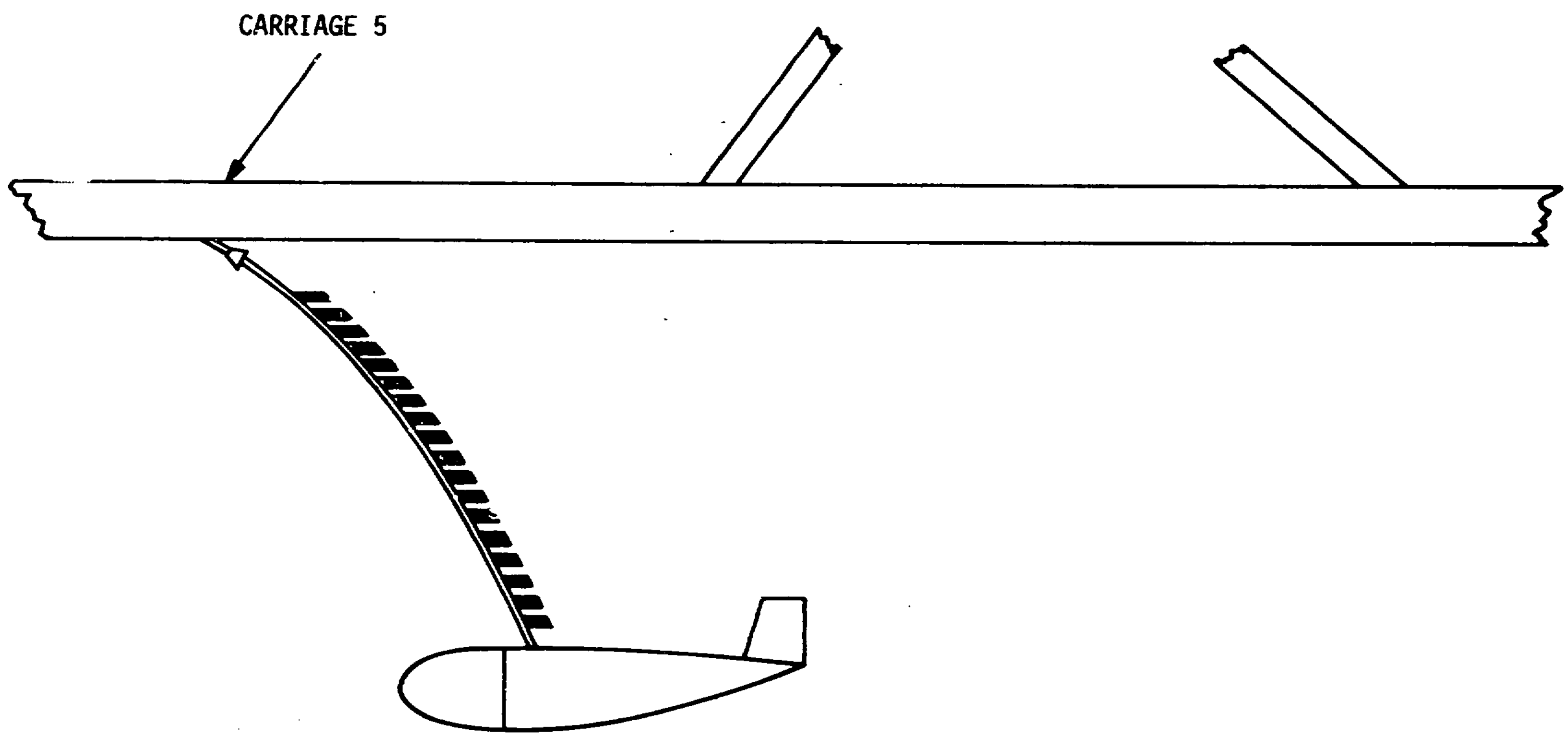


Figure 7 - General Towing Arrangement for the Inverted Condition

The model configurations evaluated are identified in Table 3. The evaluation was made for nominal speeds ranging from 4 to 25 knots. Certain configurations were not evaluated at the higher speeds due to structural limitations of the model and the vertical strut assembly.

RESULTS

The quantitative results of the evaluation include the towline tension and angle measured at the buoy model as well as the buoy pitch angle. These results are presented graphically as functions of speed in Figures 8 through 16.

Other results consist of observations of the buoy and antenna performance during the evaluation. For the configurations with the antenna extended, the length of antenna extending out of the water went through large lateral oscillations, increasing in magnitude and frequency with speed. At 20 knots the frequency of the antenna oscillations, as determined from movies, was about 3 hertz. Ventilation developed down the antenna as it was towed through the air/water interface.

The buoy model provided a stable platform throughout the investigation. The model remained stable when evaluated without antenna up to 25 knots. The model was stable up to speeds of 22 knots with the antenna retracted and 20 knots with the antenna extended.

Cavitation developed in the tip vortices occurring along the outer edges of the model as illustrated in Figure 17. Cavitation inception

TABLE 3 - IDENTIFICATION OF MODEL CONFIGURATION

Configuration	Towpoint Location, percent of chord length	Static Depth, feet	Meters	Antenna Condition	Stabilizer Angle, degrees
1	37	1.9	(0.58)	Without	-4.6
2					-6.3
3					-7.0
4				Retracted	-5.7
5				Extended	-2.6
6		8.2	(2.50)	Retracted	-3.0
7					-4.0
8					-5.0
9	40	1.9	(0.58)	Without	-3.7
10					-4.8
11				Retracted	-0.5
12					-1.1
13				Extended	0
14		8.2	(2.50)	Without	-2.2
15					-3.0
16					-3.5
17				Retracted	-0.4
18					-0.9
19					-1.6

Symbol	Configuration	Antenna	Depth, ft.	i_c	T.P.
⊙	1	Without	1.9 (0.58m)	-4.6°	37%
⊡	2	Without	1.9 (0.58m)	-6.3°	37%
◇	3	Without	1.9 (0.58m)	-7.0°	37%

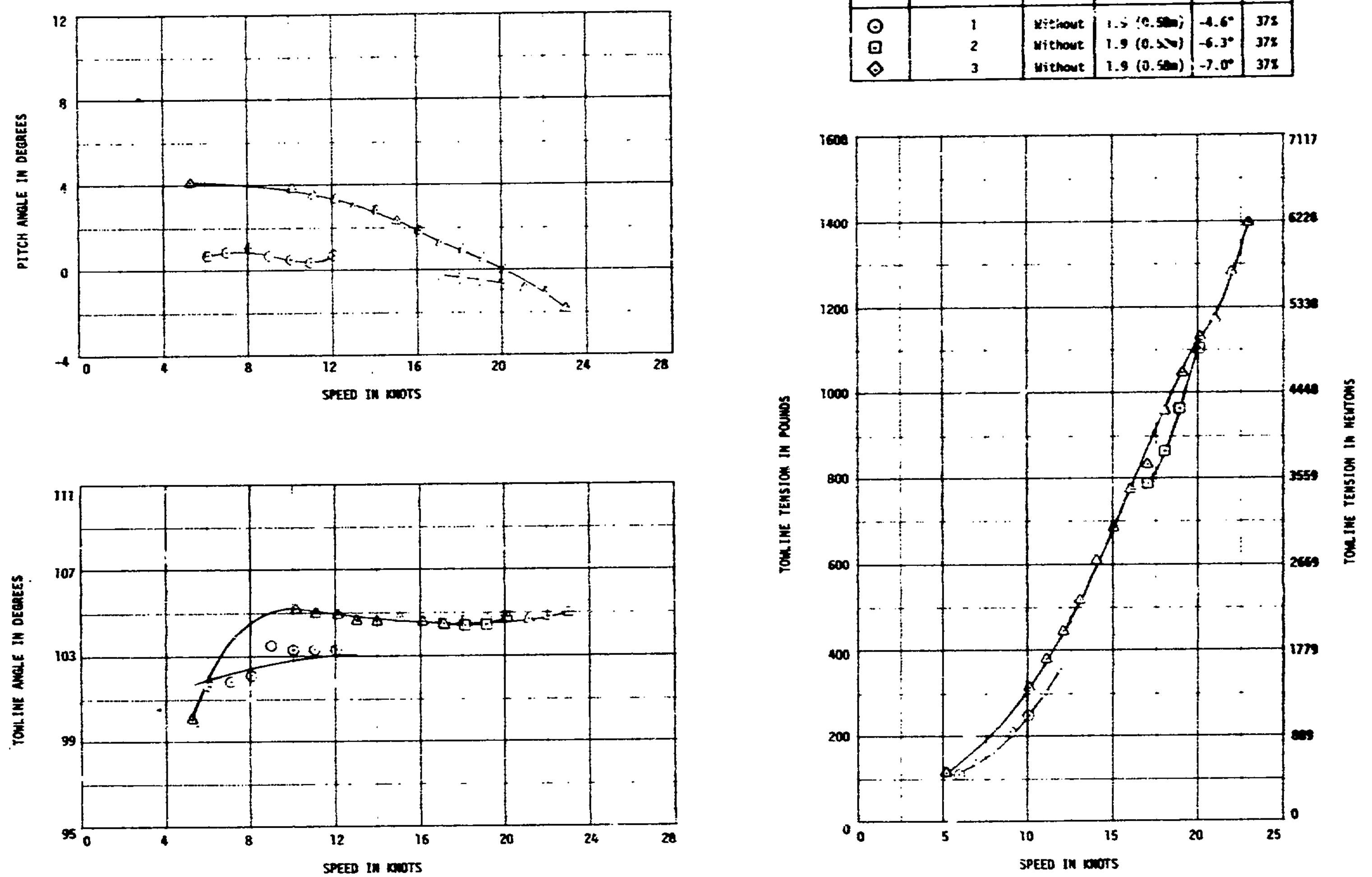
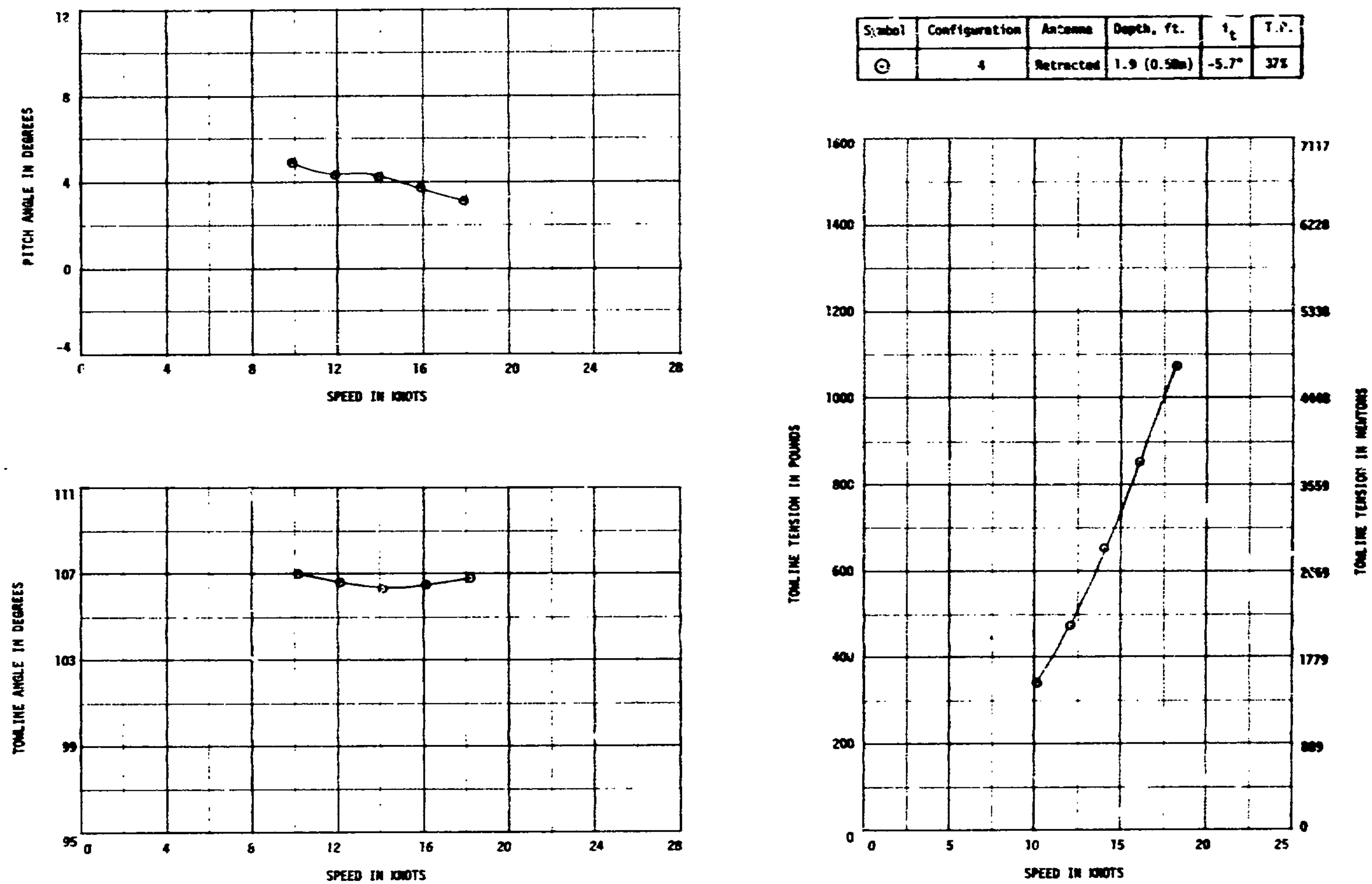


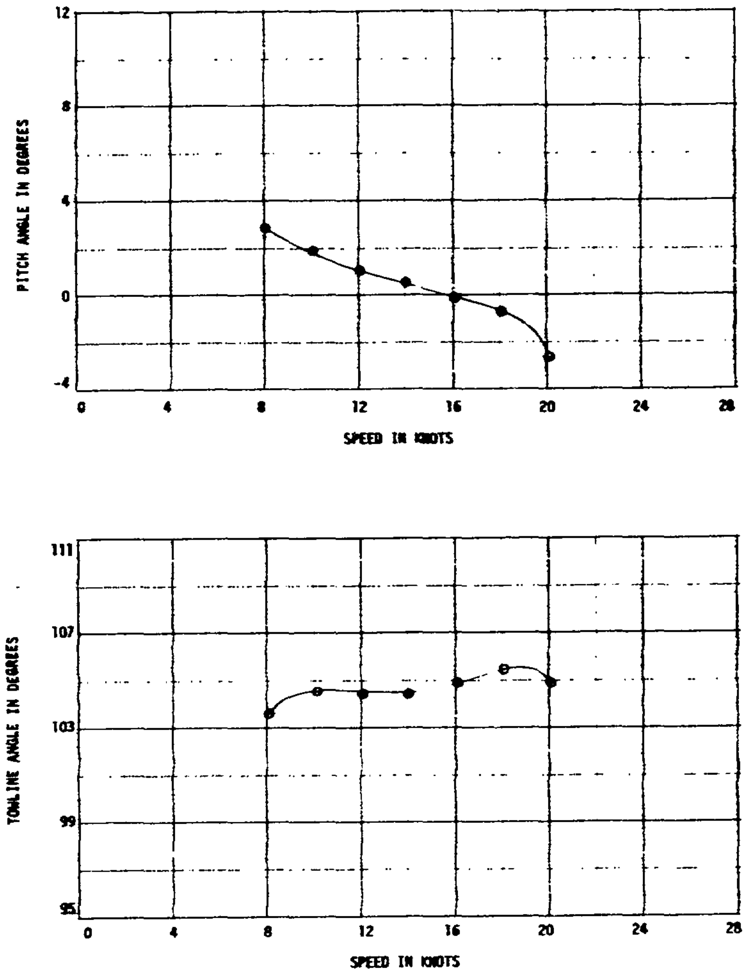
Figure 8 - Hydrodynamic Characteristics of Configurations 1, 2 and 3



Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	4	Retracted	1.9 (0.58m)	-5.7°	37%

Figure 9 - Hydrodynamic Characteristics of Configuration 4

Symbol	Configuration	Antenna	Depth, Ft.	i_t	T.P.
⊙	5	Extended	1.9 (0.58m)	-2.6°	37%



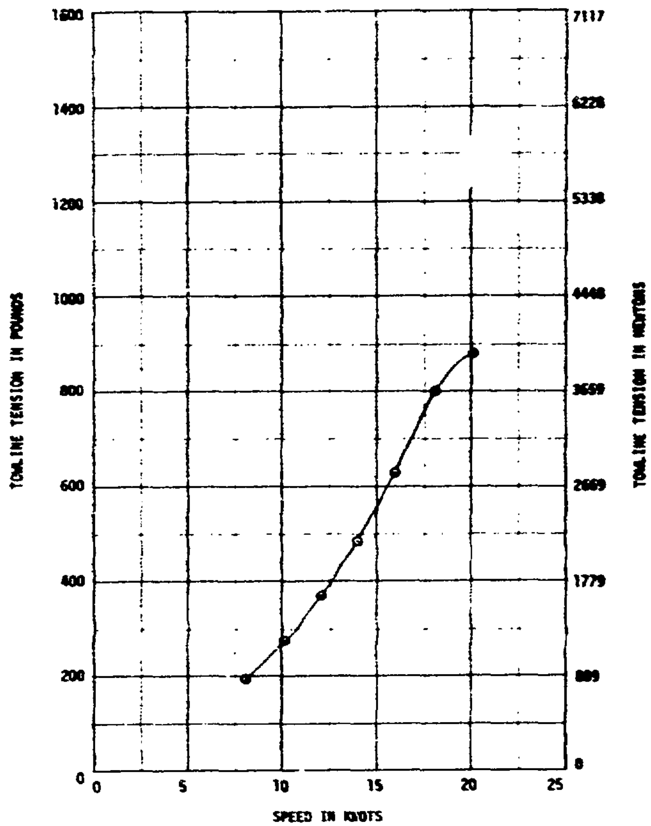


Figure 10 - Hydrodynamic Characteristics of Configuration 5

Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	6	Retracted	8.2 (2.50m)	-3.0°	37%
⊡	7	Retracted	8.2 (2.50m)	-4.0°	37%
◇	8	Retracted	8.2 (2.50m)	-5.0°	37%

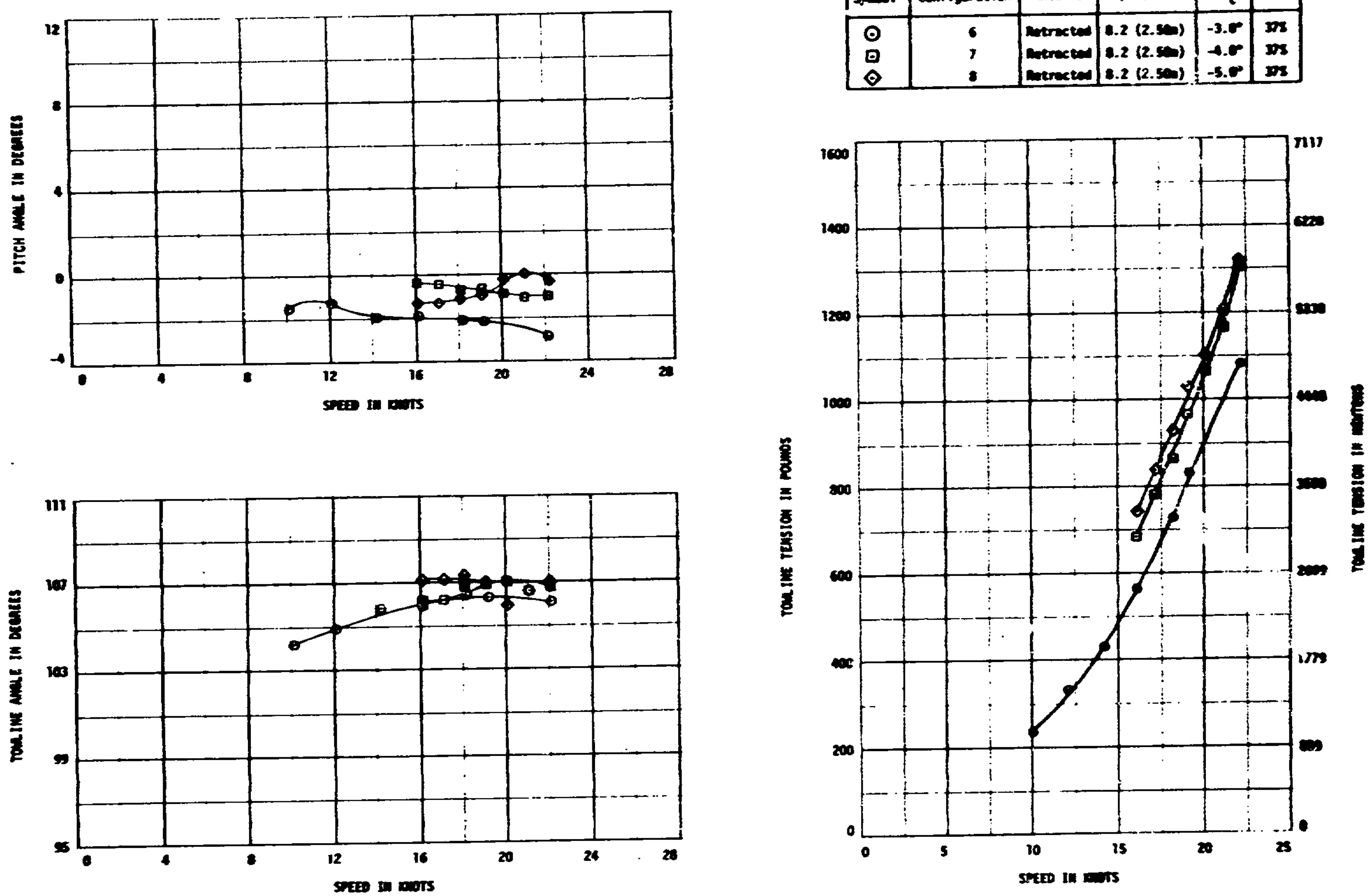


Figure 11 - Hydrodynamic Characteristics of Configurations 6, 7 and 8

Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	9	Without	1.9 (0.58m)	-3.7°	40%
⊡	10	Without	1.9 (0.58m)	-4.8°	40%

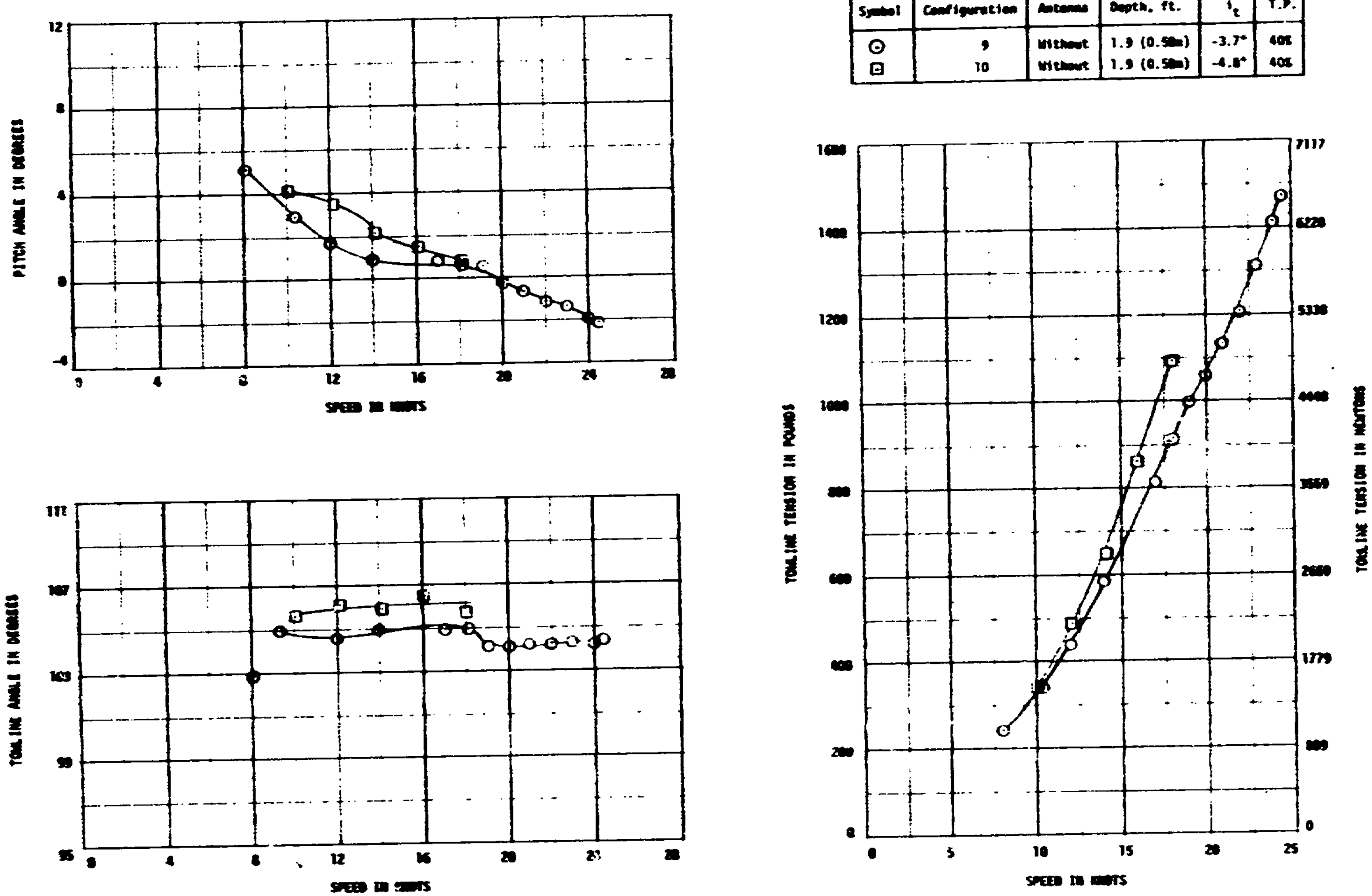
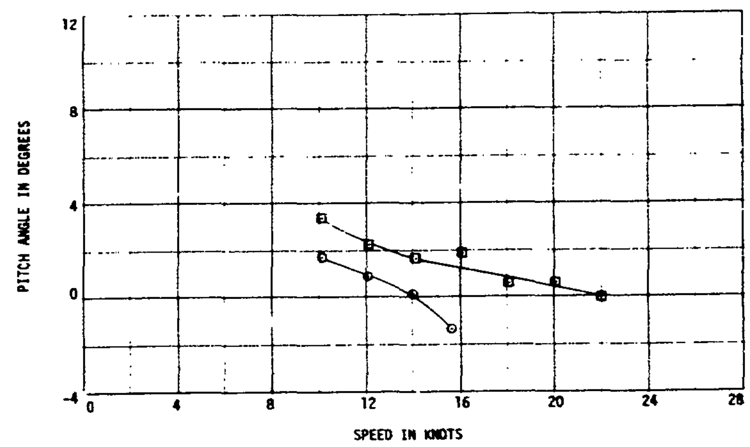
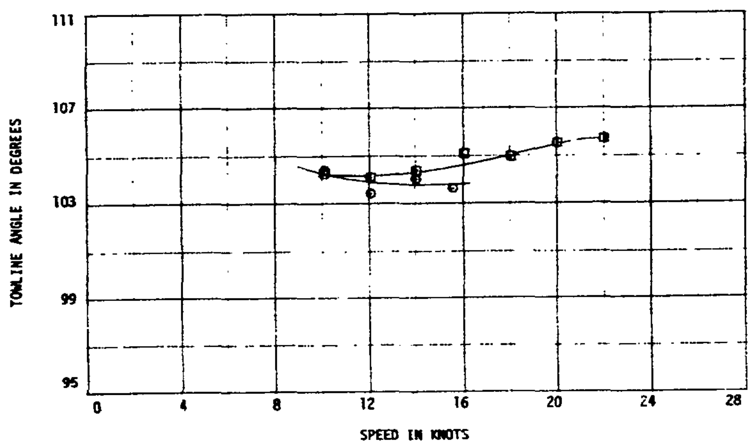


Figure 12 - Hydrodynamic Characteristics of Configurations 9 and 10

Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	11	Retracted	1.9 (0.58m)	-0.5°	40%
⊡	12	Retracted	1.9 (0.58m)	-1.1°	40%





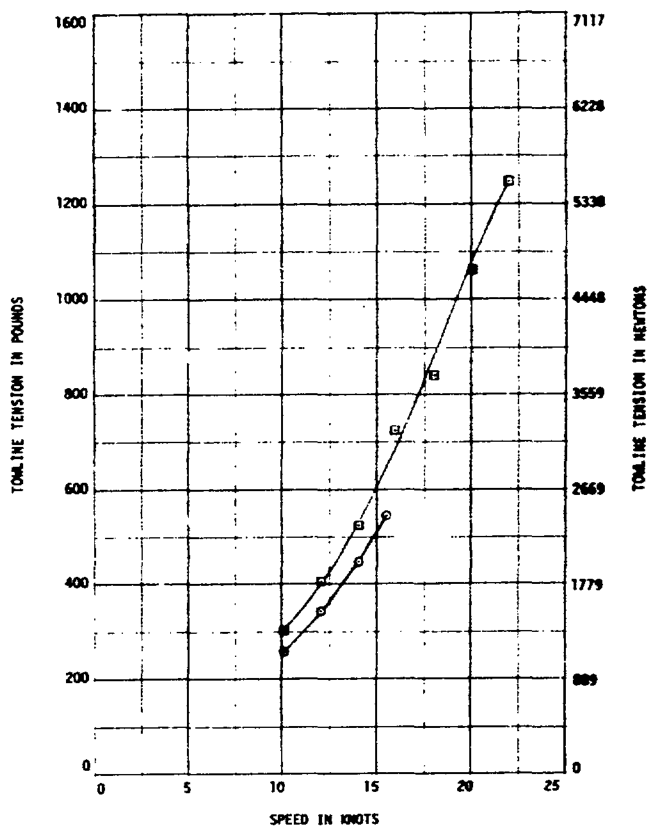
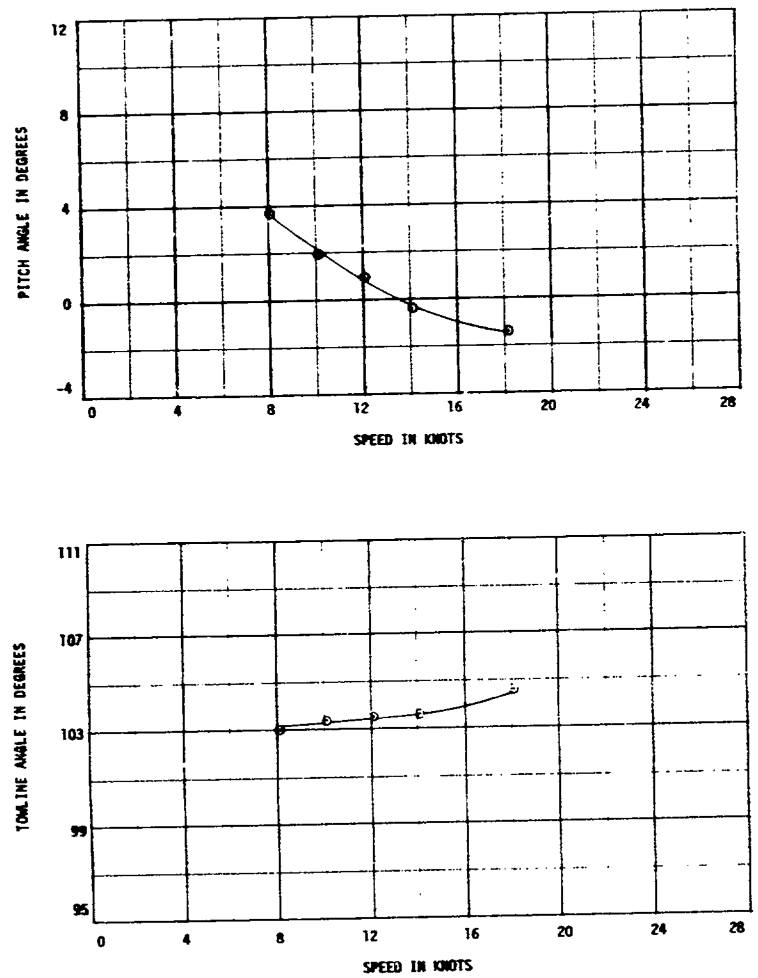


Figure 13 - Hydrodynamic Characteristics of Configurations 11 and 12

Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	13	Extended	1.9 (0.58m)	0	40%



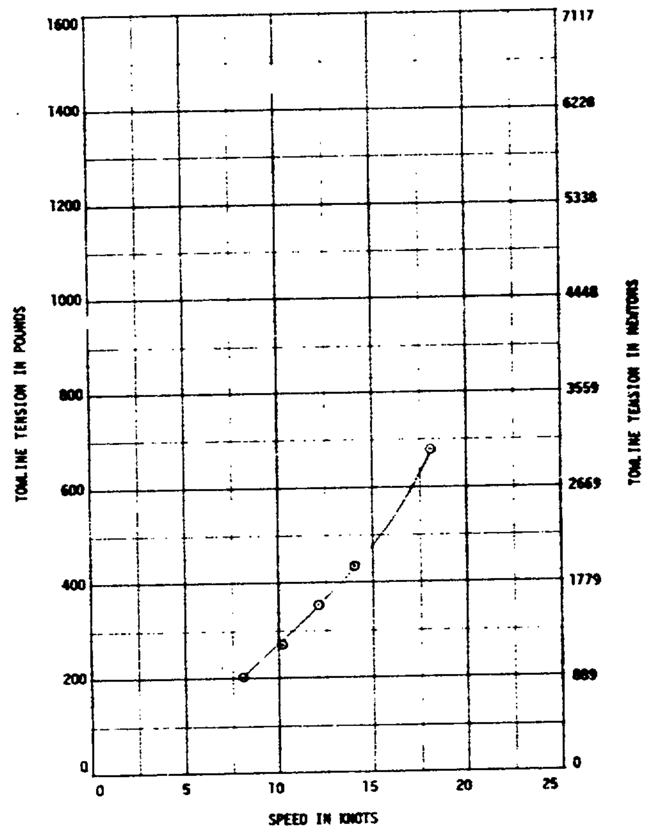


Figure 14 - Hydrodynamics Characteristics of Configurations 13 and 14

Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	14	Without	8.2 (2.50m)	-2.2°	40%
⊡	15	Without	8.2 (2.50m)	-3.0°	40%
◇	16	Without	8.2 (2.50m)	-3.5°	40%

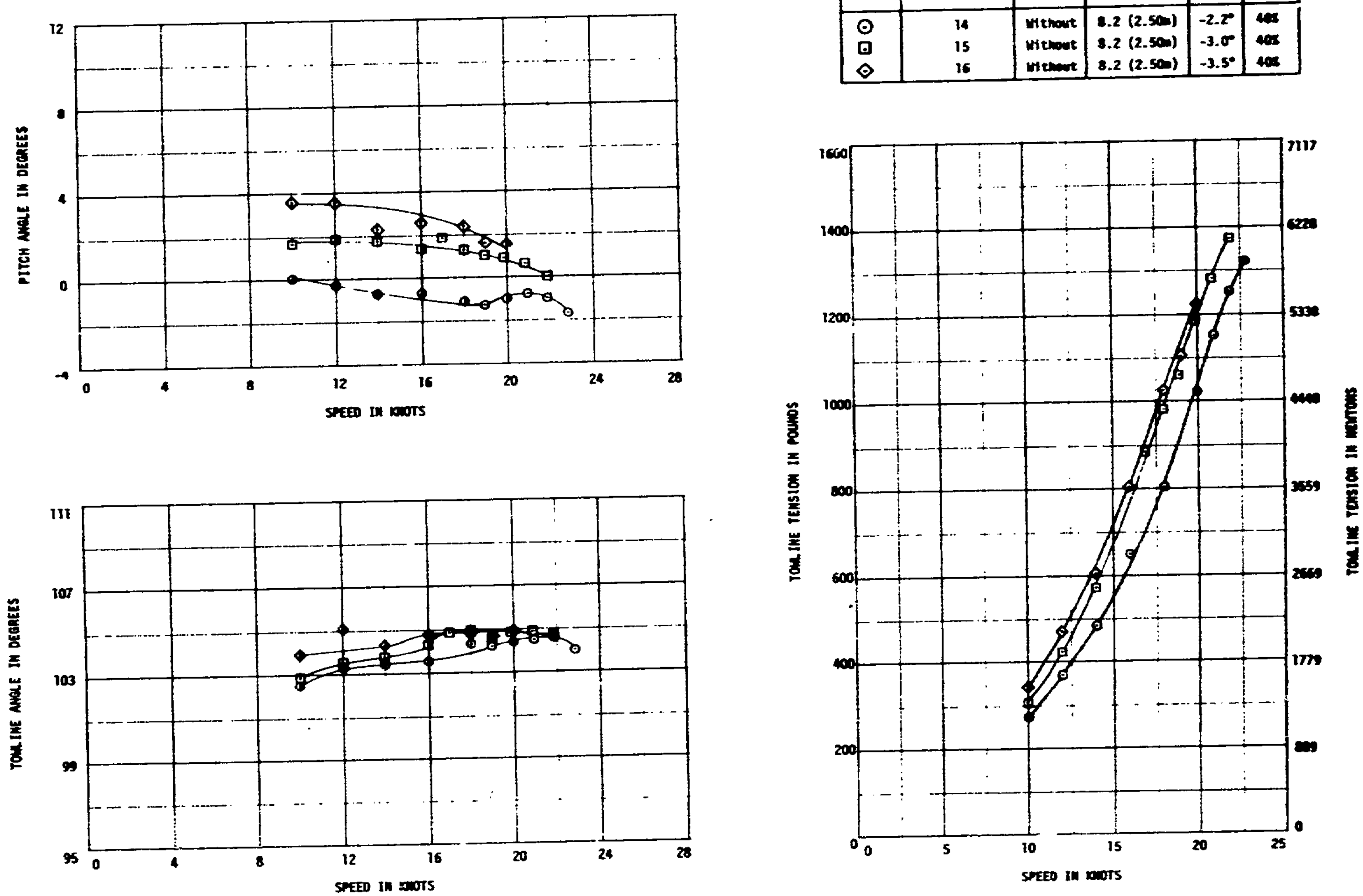
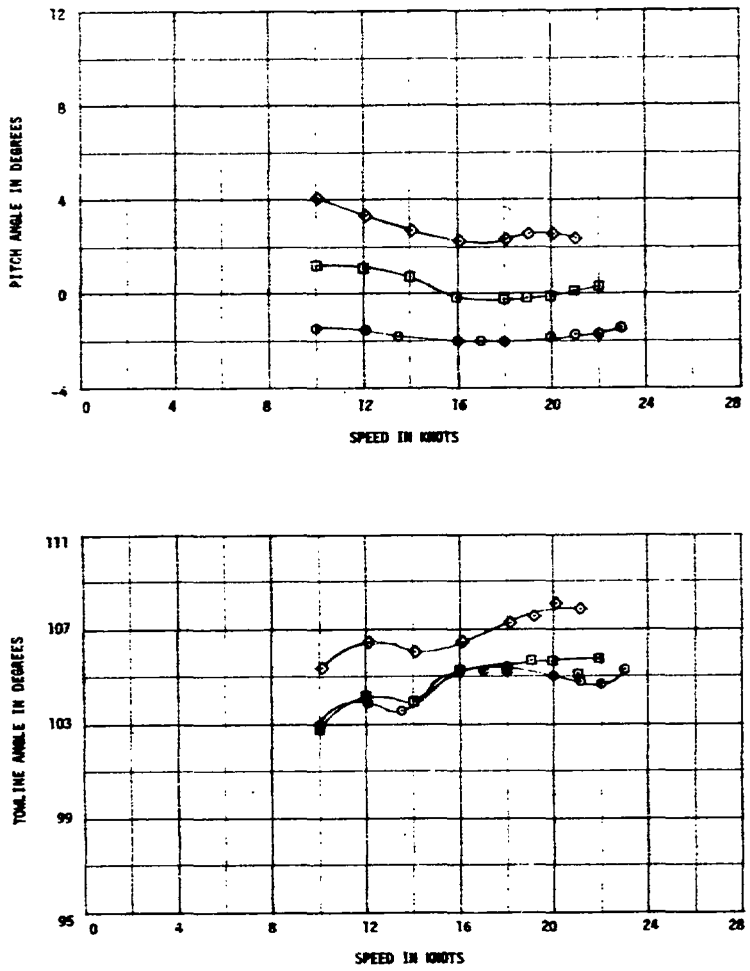


Figure 15 - Hydrodynamic Characteristics of Configurations 14, 15 and 16



Symbol	Configuration	Antenna	Depth, ft.	i_t	T.P.
⊙	17	Retracted	8.2 (2.50m)	-0.4°	40%
⊡	18	Retracted	8.2 (2.50m)	-0.9°	40%
◇	19	Retracted	8.2 (2.50m)	-1.6°	40%

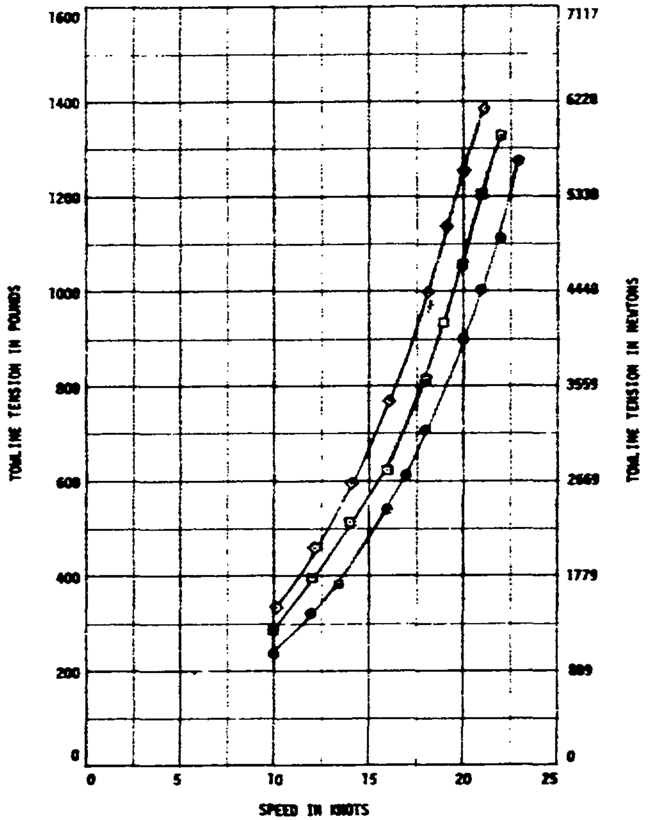


Figure 16 - Hydrodynamic Characteristics of Configurations 17, 18 and 19

Figure 17 - Tip Vortices Cavitating at 19 Knots

occurred typically at 16 knots; however, a fully cavitated vortex sheet over the model never developed. The cavitation of the vortices at 20 knots extended approximately 10 feet (3.05 meters) downstream.

DISCUSSION OF RESULTS

For most configurations, as the speed increases beyond 8 knots the pitch angle decreases, as seen in Figures 8 through 15. This results in the tension increasing at a slower rate than if the buoy maintained a constant pitch angle.

For the two towpoint locations at similar speeds and angles of attack, the 40 percent towpoint location develops approximately 10 percent lower tensions with slight improvement in life-to-drag ratios.

The sensitivity of the pitch angle to changes in the stabilizer angle can be seen in Figure 16 where a change in stabilizer angle of 0.5 degrees from -0.4 to -0.9 resulted in a change in pitch angle of as much as 3.0 degrees. This phenomenon is more evident with the buoy model operating at the smaller pitch angles.

CONCLUSIONS

Based on the results of the investigation, the following conclusions are drawn:

1. A buoy with a NACA 4424 shape will perform satisfactorily at speeds up to 25 knots.

2. A buoy twice the size of this model will provide sufficient volume for payload, static buoyancy, and dynamic lift to replace the existing AN/BSQ-5 buoy.

DTNSRDC ISSUES THREE TYPES OF REPORTS

(1) DTNSRDC REPORTS, A FORMAL SERIES PUBLISHING INFORMATION OF PERMANENT TECHNICAL VALUE, DESIGNATED BY A SERIAL REPORT NUMBER.

(2) DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, RECORDING INFORMATION OF A PRELIMINARY OR TEMPORARY NATURE, OR OF LIMITED INTEREST OR SIGNIFICANCE, CARRYING A DEPARTMENTAL ALPHANUMERIC IDENTIFICATION.

(3) TECHNICAL MEMORANDA, AN INFORMAL SERIES, USUALLY INTERNAL WORKING PAPERS OR DIRECT REPORTS TO SPONSORS, NUMBERED AS TM SERIES REPORTS; NOT FOR GENERAL DISTRIBUTION.